Various Mathematical and Geometrical Models for Fingerprints: A Survey

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***Abstract* - Fingerprints are the most universal, unique and persistent biometrics. The growing interest and eventually the need for advanced security, privacy and user convenience has put an access to fingerprint recognition, beyond the other biometrics recognition systems. Despite the ingenious methods improvised to increase the efficiency of detection in growing identity frauds, the growing demands for fingerprint as a biometric recognition system has quickly become overwhelming. Major challenges coming in the way of a robust fingerprint recognition system are the presence of noise, cuts, wet or dry images, different pressure and skin conditions, etc. The main objective of this paper is to review the extensive research on fingerprint recognition over the last decades and to address the present challenges. A comprehensive analysis can be made from the tabular form of the presented summary table using various techniques and features. Finally, the future directions of fingerprint recognition are explored.**

Keywords – Biometric, Local and Global features, Minutiae.

I. Introduction

Biometric recognition refers to the use of distinctive physiological and behavioural characterstics called biometric identifiers for automatically recognizing individuals [1]. An important issue in designing a practical biometric system is to determine, how an individual is recognized? Based upon application context, a biometric system may be classified as a verification system or identification system [2]. In comparison to traditional keywords or passwords or token based systems, the biometric identifiers are considered more reliable for recognition for they cannot be forged easily [3].

Fingerprint recognition is among one of the most ultimate and desirable research areas in the field of pattern recognition. Owning to its persistency, distinctiveness and immutability, fingerprints are used as the most attractive biometric identifier worldwide. For achieving high efficiency, better security and public convenience, provokes the need and importance of a robust fingerprint recognition system [4]. Further due to its security and law enforcement applications, and being a valuable answer to various private and government organizations in growing identity frauds, fingerprints are the current subject of interest and the emerging priority [5]. The important issues in fingerprint recognition are the affected performance due to the major challenge to various skin conditions, noise or scars present in an image and what features to be used to categorize fingerprint classes.

The typical process of fingerprint recognition is illustrated in Fig 1. There are mainly 4 steps: preprocessing, feature extraction, comparison and matching. Image enhancement belongs to preprocessing. Image enhancement is done to improve the image quality by a fingerprint recognition system [6]. Next block is feature extraction, where different features are extracted for comparison and matching [7], [8]. Next block is for comparing the extracted feature with the previous data stored in the database [9]. The last and the final stage is matching or indexing, which is done either by classification or matching [10]. Fingerprint classification and indexing techniques speed up the search in fingerprint based identification systems.. The current state of the art algorithms for fingerprint matching are too expensive [11].

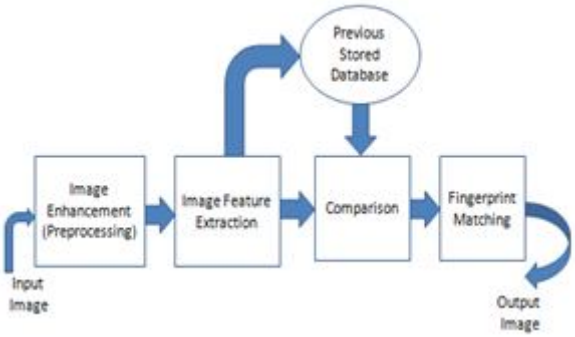

Figure 1: Generalized Block Diagram of Fingerprint Recognition System

Section II elaborates the various approaches of fingerprint recognition. In particular, it discusses the fingerprint features used for distinguishing fingerprint classes and reviews the methods of enhancement, extraction and classification that motivates better recognition of an image. Further, a comprehensive analysis is made in a tabular form at the end of section II. Section III & IV sums up with the conclusion and future aspects.

II. Related Works

This section glints through various fingerprint recognition algorithms and methods through various approaches like mathematical, neural and geometric, using different features for enhancement, extraction and classification.

A. Mathematical Approaches

F. Turroni et al. propose a method to estimate the ridge orientation deploying STFT and gradient method to reduce an error [12] and other in [33].

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TABLE I. : SUMMARY OF VARIOUS TECHNIQUES

MATHEMATICAL APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	M.Liu et al.[19]	Polar complex Moments	NIST & FVC	Singular regions.	Fingerprint Indexing.	Better performance than the earlier mentioned.
2.	H. Tairi et al.[20]	STFT & Hu Moments	FVC	Singular regions.	Fingerprint Matching.	Better Approach than the earlier mentioned.
3.	A. K. Jain et al.[10]	Wavelet transform & Gabor filters.	FVC	Level 3 features. (pores)	Fingerprint Matching.	Error rate decreased.
4.	D. Maltoni et al.[21]	Parzen window method with Gaussian kernel.	FVC	Singular regions.	Fingerprint Classification.	Better than previous mentioned.
5.	A. K. Jain et al. [11]	Gradient based re-construction algorithm.	FVC	Minutiae	Orientation field & matching.	Consistent reconstructed image.
6.	N. Manivan et al. [8]	Highpass filtering & Correlation filtering.	FVC	Pores	Extraction & Location.	Distinguishable location & size.
7.	J. Zhou et al. [22]	DORIC, gradient & polynomial methods & SVM.	NIST 4, FVC02	Singular Points.	Singular point verification.	More robust & accurate.
8.	H A Qader et al. [23]	Zernike Moments.	FVC 2002 DB1	Core points.	Fingerprint matching.	High accuracy matching.
9.	D. Singh et al.[24]	Hidden Markov Model.	FVC 2002 DB1	Orientation field	Fingerprint matching.	Error rate decreases.
10.	A. Pokhriyal et al. [2]	Pseudo Zernike moments & wavelets.	FVC 2000 DB1	Local & global features.	Fingerprint verification.	Better rate is obtained than the compared one.
GEOMETRIC APPROACHES						
	Author	Technique Used	Database	Features used	Recognition	Efficiency
1.	Z.M. Kovacs et al .[25]	Harmonic coefficients estimation & geometric approach.	NIST SDB4	Ridges	Identification & classification.	Less computation time in identification.
2.	G. Zhang et al. [26]	Global alignment.	NIST & FVC	Minutiae	Identification	Better approach than previous one.
FILTERING APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	B. Popovic et al.[27]	Log- Gabor filtering in frequency domain.	FVC	Minutiae	Fingerprint Enhancement to remove spurious minutiae.	More efficient than older one.
2.	A. K. Jain et al. [28]	Fast enhancement algorithm.	MSU DB	Ridges & valley.	Fingerprint enhancement.	More accurate than older one.
NEURAL APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	C. Yu et al.[17]	Shrinking & Expanding algorithm Fuzzy zones also used.	FVC	Singular points	Removal of noisy singular points & detecting them.	Distinguishable location & size.
2.	J. K. Gupta et al.[29]	Artificial neural network.	FVC	Minutiae	Fingerprint matching.	More efficient & robust than earlier mentioned.
SEARCHING APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	R. Cappelli et al.[30]	Exclusive classification & indexing based on scalar & vector features.	NIST DB14	Ridge orientation.	Fingerprint Indexing.	More efficient & faster than older one.
CLASSIFIER APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	H. Xu et al.[31]	A novel algorithm.	FVC	Singular points & Minutiae.	Fingerprint Verification.	Better than the technique compared.
MODEL & RESOLUTION BASED APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	D. Weng et al.[32]	Zero Pole Model & Least mean square estimation.	FVC	Ridges.	Singular points detection.	Multiple resolution obtained, hence more robust & better.
OTHER APPROACHES						
	Author	Technique Used	Database	Features Used	Recognition	Efficiency
1.	L. Zhang et al.[7]	Pore Valley Descriptor.	FVC	Pores	Pore extraction & Matching.	Better than older one.
2.	A. K. Jain et al. [9]	Classification algorithm.	NIST 14 DB	Feature vector code.	Fingerprint classification.	Better accuracy than earlier compared.

B. Geometric Approaches

Further, a 3D technique is introduced by D. Maltoni et al. using minutia angles and distances for fingerprint recognition [13].

C. Neural Approaches

L. Ji and Z. Yi propose a method to investigate the effect

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of neurons, using neural network approach through a fast and accurate orientation field estimation algorithm introduced in [14].

D. Filtering And Classifier Approaches

H. Choi et al. discuss a matching algorithm, using a Breadth first search for minutiae and ridge features detection. Further, the searching approach combines two more methods for minutiae extraction, using DRLC and SRLC as given by J.H. Shin et al. and the Variable threshold method, based on score difference and ratio for fingerprint indexing by D. Maio et al. [15].

E. Model Based Approaches

D . Zhang et al. further identify the optimal resolution for an automated fingerprint recognition system, introducing a resolution method using acquisition device [16]. Similar approach is also used by C. Yu et al. for fingerprint recognition [17].

F. Other Approaches

A.K. Jain further employ Gabor filters and goodness index for fast enhancement and verification of a fingerprint [18]. Latent fingerprints are matched using ridge features to increase the identification rate by A.K. Jain [34]. Further, a comprehensive analysis can be done with the following table 1 using different features through different approaches in fingerprint recognition.

III. Concluding Remarks

From the above survey, we can conclude that fingerprint continues to be one of the most important and attractive biometric identifiers than other biometrics, and inspite of so many techniques and proposed algorithms, fingerprint recognition is still a challenging task in the present scenario. Hence the problem can be formulated to go further for optimal results. A comparative study can be found from Table1, comparing different techniques using different features. It is still difficult to have accurate algorithms capable of extracting salient features and matching them in a sturdy way, both in poor quality images and in small area regions. There is a popular misconception that automatic fingerprint recognition is a fully solved problem. On the contrary, fingerprint recognition is still a challenging and important pattern recognition problem.

IV. Future Work

The future study of fingerprint recognition might use combination of features of level 1, level 2 and level 3. The fairly exhaustive survey points to the fact that in future work, one may stand benefitted by a further exploration of relative advantages of combining not only the feature levels but also by exploration of multiple approaches of tackling these features information.

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